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The Electric Melting Furnace: The Early History of the Electric Melting Furnace and its Development into Various Commercial Types

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HISTORY OF THE ELECTRIC FURNACE

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What I am going to tell you is not new, but it will supply a background for the following papers by stating some of the historical relations in the development of the electric furnace.

About 1877 Siemens got the idea that it would be possible to melt steel commercially by the use of the electric arc. He spent a great deal of money and exercised a good deal of ingenuity in trying to melt steel in a crucible by means of the electric current. He tried this in two ways: First of all to melt the steel by radiation from an arc, and second by making the steel one pole of an arc.

He took a crucible, bored holes in the sides near the top, put electrodes through these holes, placed the metal in the bottom and a lid on top and then started an arc, melting the steel by radiation. That was the first arc-radiation furnace.

He also took a crucible, using but one electrode passing through the lid and making the steel itself one of the electrodes of the arc. The upper electrode was comparatively easy to design, but the lower electrode (to take the current away from the steel itself) was the cause of trouble. He bored a hole through the bottom of the crucible, reinforced it outside by a block of concrete, and screwed in a sort of a plug of soft iron. He relied upon this for carrying away the current, it being in contact with the melted steel inside and cooled by the air outside. His proposition attracted much attention. In some cases he obtained a thermal efficiency as high as 50 per cent.

He tried to make this furnace run commercially, but it did not prove effective due to the uncertain nature of the iron connection through the bottom. He spent a great deal of money trying to make it a commercial success, but was unable to do so. He did, however, get some fairly high thermal efficiencies, but his apparatus was not good enough for commercial use. That sums up in a few words what Siemens tried to do and what he accomplished.

The next to experiment with the electric furnace to melt steel by radiation from the arc was Captain Stassano of the Italian Army. He built a furnace four feet in diameter and three feet high, with three electrodes passing in through the upper parts of the walls, coming together in triangular formation above the bath, and using a three-phase arc. The furnace was capable of holding about a ton of steel. It was used commercially in Turin, Italy. Because of the cheapness of power—$12.00 per h.p.-yr.—and with scrap steel at about $5.00 per ton, he was able to charge his furnace, melt down the steel, pour it into castings, and successfully compete with the steel made in open-hearth furnaces or in Bessemer converters. This was a direct development of Siemens' idea—melting by radiation from an arc. From forty to fifty furnaces of this type are at present in operation throughout the world.

There are other furnaces of a somewhat similar character, heated by radiation from the arc. Sometimes the arc is changed a little in shape. Such a one is the Rennerfelt furnace, which is essentially of the same general type, though differing in details. It consists of two horizontal and one vertical electrodes, which project the arc like a blowpipe on the surface of the metal.

There are still other types of the arc furnace. There is the rocking arc-furnace, in which the electrodes pass through the sides of the furnace, but the metal is rocked so that it is uniformly heated, thus combatting unevenness of temperature caused by intense heating near to the arc. This particular modification of the arc-radiation furnace has been found very useful in the melting of alloys containing volatile metals, such as, particularly, brass.

The other type of furnace devised by Siemens, with the arc passing from the electrode to the metal, is known as the arc-resistance furnace. In such furnaces the larger part of the energy which melts the metal is generated in the arc. This idea was first worked commercially by Girod, a Swiss electrical engineer, who conceived the idea of taking a regular saucer-shaped, steel-melting hearth and putting through the bottom of it a large hole, through which was inserted a soft, low-carbon steel rod. The electrode passing through the hearth was eighteen inches long; in running it melted six inches and left twelve inches solid. This automatically sealed it, and the current was taken away from the projecting end outside, which was water-cooled. One or more of these heavy electrodes was arranged in parallel through the bottom of the hearth. Ten, twelve, and even twenty-ton furnaces are in operation on this design. All grades of steel are successfully made in these furnaces. The Bethlehem Steel Company runs a ten-ton Girod furnace, melting cold charges, at Bethlehem.

Keller, in France, is making steel for the French Government with a modification of Girod's idea. He built a furnace in which he distributed electrodes in the hearth by taking a plate and putting it in the bottom of the furnace under the refractory material, and attaching to it a number of half-inch rods which came up to the working surface where the metal lay. The refractory material was rammed around these rods. He had two to three hundred half-inch rods forming a regular grid coming through the bottom of the furnace to which electrical attachment was made, ramming in between them broken carbon in order to make the mass more conductive. If he rammed in carbon alone it would be dissolved out by the steel and the bottom would keep coming up, so he used a mixture of carbon and magnesite, which proved very satisfactory, covering it up with a surfacing of magnesite. He built a large number of furnaces which have operated very satisfactorily with this grid of electrodes embedded in the bottom.

Someone then thought: "Is not the material of the hearth conductive enough, when hot, to carry the current?" The first furnace of that type that I saw was in operation in Sheffield, England. The method followed was to take a grid electrode and embed it in the hearth, leaving the prongs embedded but not quite reaching through the hearth to the metal above it. When cold, this refractory layer was an insulator, but when hot a good enough conductor; and so a direct electric connection between the bottom electrode of the furnace through the hearth material to the metal bath was formed.

The hearth material itself becomes impregnated with oxide of iron during use, and thus becomes better conducting, so much so that the furnace can be started up cold. Electrical connection is thus formed through the material which forms the basic hearth itself.

A number of furnaces have been designed on this principle, with the electrode embedded in the bottom of the hearth. They are sometimes built with the hearth electrode of graphite and iron, or of iron with graphite terminals, embedded in the hearth material, with the hearth material packed and rammed in on top of it. These furnaces are further developments of Siemens' idea of taking the current off from the bottom of the containing vessel.

The Heroult arc furnace uses two electrodes—one to put current into the charge and the other to carry it away. The idea is to have two arcs in series, to have current passing from one electrode through the slag to the metal, through the metal, and thence back to the other electrode. With very cheap power, labor, and scrap material available, Heroult was in a position to make very large profits, and founded a successful steel business. Heroult did more perhaps than anyone else to make electrical steel commercial.

Heroult also devised and obtained French patents for a combined furnace, which was intended for use as a Bessemer converter and electric furnace. His electric furnace was similar in shape to the open-hearth furnace, except that it was heated by electrodes passing through the roof. He interested the U. S. Steel Corporation in his patents and sold them for a large sum. The U. S. Steel Corporation has actively made use of them itself, and has also built furnaces for other people. The furnaces are splendidly designed, as well as being on a good working principle. The type having two electrodes and two arcs has been largely replaced by those having three electrodes and three arcs, for the latter three-phase type is the cheaper and more adaptable form of furnace. There are about two hundred and fifty of these furnaces in use in the United States.

There is another type of furnace which does not use the arc—the resistance furnace, where the metal is heated by the resistance of a solid or liquid material. There are a number of such furnaces. The first was devised by Gin, who used simply a ractangular hearth provided with a long serpentine groove connected with two heavy terminals, and capable of carrying a very heavy current. The object was to melt down the metal by its own resistance, and to keep it at the proper temperature. Nothing but the resistance of the metal itself, lying in the groove, was relied upon to melt it and keep it at the correct temperature while being refined.

The resistance-radiation furnace is one where the metal is heated by radiation from the resistor, the latter being heated by the direct passage of the current. That is the principle of the Bailey furnace which is used for heating bars and ingots and for melting metals such as brass, but not yet for melting steel. The channel filled with broken carbon is just beneath the roof of the furnace, which collects the heat generated as it is reflected against it, and radiates it back onto the charge on the hearth.

There is another type of this resistance furnace where the material to be melted is put in crucibles and the conducting material by which it is to be heated (the resistor) is packed around the crucibles. This type of furnace does not, however, find much popularity, for it has defects and shortcomings which prevent it from becoming a commercial success, though it is very satisfactory as a laboratory furnace.

There is a type of resistance furnace which depends upon the pinch effect. Liquid metal in small channels communicating with a larger bath of metal, is heated by its own resistance. This is the basic principle of the Hering furnace. The electrodes carrying current to these channels are water-cooled. This type of furnace has received many modifications, among which is the use of current generated in the tubes by induction, so doing away with electrodes (Ajax-Weil-Hering furnace.) This introduces complications, but yet it has merit by doing away with electrodes, and is now in successful operation.

The induction furnace is also a resistance furnace; it was originated by Mr. Colby, of Newark. He thought it possible to melt metal by means of induced currents. He experimented at the General Electric Company laboratories and took out patents, but never brought it to a commercial outcome. Ferranti conceived the same idea in England at about the same time. The first to use this idea commercially was Kjellin in Sweden, about 1902. He used bars of steel which had been made in other furnaces, merely melting them down in this furnace which he used as a melting crucible. He built a small furnace of 500-pound capacity, then one of 1000-pound, and made steel in large quantities.

The Germans (Roechling and Rodenhauser) took up the idea and increased the size of the furnace by multiplying it—making a combination furnace of two circles. Even a three-circle furnace run by three-phase current, has been devised.

It is a great feat to construct these complicated furnaces and to get them to work—to melt steel and yet to keep the coils cool enough so that their insulation is not destroyed. The principal drawback with this type of furnace is its lack of exposed metal surface, so that it is difficult to refine material in them. They are also very expensive, and an accident to them is a very serious matter.

There is a type of induction furnace which has recently been brought out by Dr. Northrup, with rapid oscillating current, which does not need a magnetic circuit, and so is simpler in design. It has many advantages over the ordinary type of induction furnace, but has also some complications not found in them. It has reached the laboratory stage and is developing hopefully toward the commercial field.

Electric Furnaces for Non-Ferrous Metals

The metals particularly in mind are brass and bronze, copper and aluminum being secondary in consideration. Brass contains zinc, a metal fairly volatile at a bright red heat. The considerable loss of zinc by volatilization must be guarded against. If brass is made in an electric furnace of the proper construction, volatilization and oxidation of zinc may be reduced to a very small amount (1 to 3 per cent).

The radiation furnace, which radiates heat directly on the metal, is very inefficient for this sort of work, boiling out the volatile materials very rapidly from the part of the surface which becomes over-heated. This disadvantage of the arc-radiation furnace has been overcome by active circulation—rocking of the furnace or circulation of the bath, thus keeping the metal at a uniform temperature. This principle is being utilized very efficiently in brass furnaces, which work by arc radiation and yet lose very little zinc by volatilization.

Having now in very summary fashion outlined the electric furnace art, particularly its development in the direction of melting metals, such as steel and brass, I will leave the field to the special writers who will tell of the particular construction and operation of their several types of electric melting furnaces.